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(article starts on next page)

Back

8th World Congress of Biomechanics

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Abstract

Introduction

Injury mechanisms for Whiplash associated disorders (WAD), caused by rear-end car accidents, are not fully understood. Previous studies have demonstrated cervical vertebral kinematics are influenced by both cervical spinal alignment [1-2] and interaction between thoracolumbar spine and seatback [3]. However, whole spinal alignment has not been well analysed for car occupants [4], despite its importance for WAD-injury mechanisms. Therefore, our aim is to investigate representative whole spinal alignments for male and female occupants.

Methods

The spinal column was scanned for eight female and seven male subjects in one occupant posture using an upright open magnetic resonance imaging (MRI) system. The wooden plate seat (seatback angle of 20 degrees) was designed to obtain a seating posture similar to previous rear impact sled tests [5]. The spinal alignment from C2 to sacrum was defined with the centres of the vertebral bodies obtained in the MRI data, and normalised by C2-sacrum length.

Spinal alignment patterns were investigated with Multi-Dimensional Scaling (MDS) [6], identifying the two MDS dimensions with largest inter-subject variance. On the 50% probability ellipsoid, four spinal alignments were calculated based on weighted average of all subjects to describe the MDS dimension (Figure1b-e).

Average gender specific spinal alignments were estimated at the average point on the distribution map for female and male subjects, separately.

Results

Limiting the MDS to two dimensions captured 87% of total inter-subject variance. The spinal alignments along the two MDS dimension are illustrated in Figures 1b and c with minor differences along the 2nd MDS dimension. Variance along the 1st MDS dimension, shifted from a slightly kyphotic cervical and less-kyphotic thoracolumbar spine to a lordotic cervical and more pronounced kyphotic thoracolumbar spine. All female subjects except one had slightly kyphotic cervical and thoracolumbar spine (Figure1b). Male subjects had large variance in spinal alignment, ranging from a slightly kyphotic spine to a lordotic cervical and pronounced kyphotic thoracolumbar spine. Average gender specific spinal alignments were estimated in Figure 1d; a slightly kyphotic or almost straight cervical and less-kyphotic thoracolumbar spine for females, and a lordotic cervical and more pronounced kyphotic thoracolumbar spine for males.

Discussion

There was a prominent relationship showing that cervical lordosis occurred together with pronounced thoracolumbar kyphosis. This was reflected in the estimated average gender specific spinal alignments. This study showed substantial difference in spinal alignment between males and females, with smaller variance for female subject than male subjects. These differences may explain some of the difference in WAD injury risk seen in real-world data.

Acknowledgements

JSPS KAKENHI 16KK0137.

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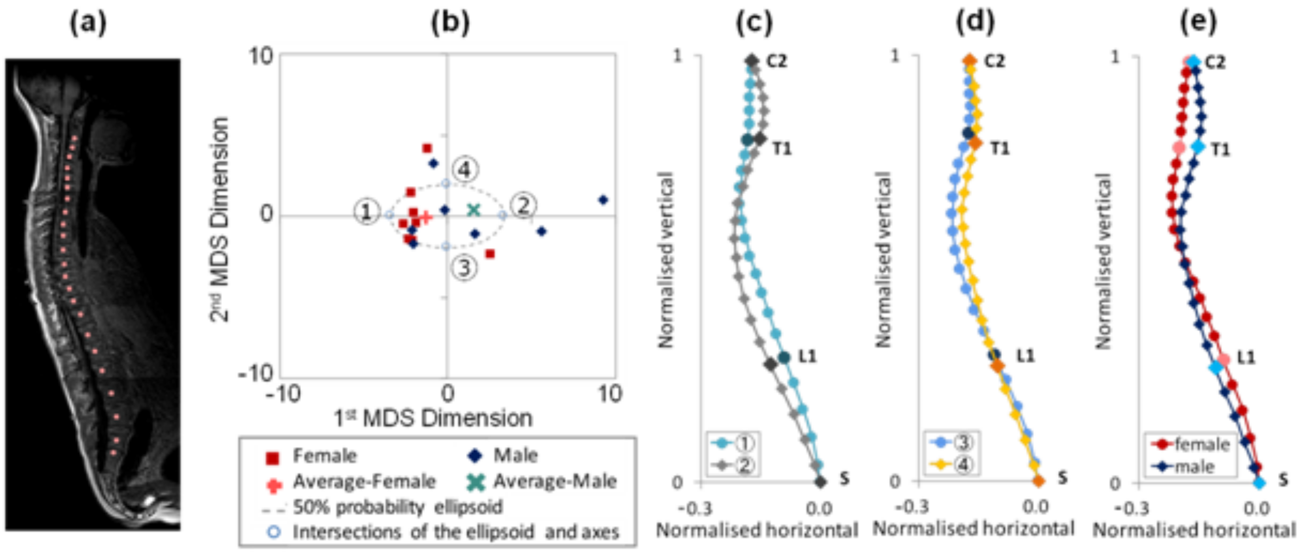

Figure 1 (a) Example of image data taken by an upright open MRI system. (b) MDS distribution map of spinal alignments. (c) Spinal alignments estimated at the intersections of 50% probability ellipsoid and the 1st MDS dimension (1 and 2), (d) estimated at the intersections of 50% probability ellipsoid and the 2nd MDS dimension (3 and 4), and (e) estimated female and male averages.